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A Project Study on Pile Foundations

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Abstract—*A pile foundation is a civil engineering concept that is, at its most basic, a substructure that is supported by piles. This type of foundation allows any type of structure to actually be supported by a layer or layers of soil. The soil is actually built up under the ground surface and the deeper the pile, or support pole goes, the more stable the structure should be.*
One of the downsides to pile foundations is that the soil must be hard enough to shore up the foundation and really keep the pile steady. Locations where the soil is very soft will not provide any support for the pile, which can be disastrous in some cases. However, pile foundations can be used in areas with very poor soil conditions as long as the soil is hard enough to hold up the piles and the structure built around them. In fact, this is one of the key uses of pile foundations.
The pile concept helps create a good, solid foundations in these types of areas. Because areas with poor soil can be difficult to excavate and may not be capable of supporting heavy structures, traditional foundations are not always an option. These types of areas are usually filled with soft clay, loose soil, boulders, high ground-water levels, and other things that make it difficult to build.By setting up pile foundations instead of traditional foundations that use spread footing, the poor soil conditions have almost no impact on the foundation.

1. INTRODUCTION

A shallow foundation is usually provided when the soil at a shallow depth has adequate capacity to support the load of the superstructure. However, in situations where the soil at shallow depth is poor, in order to transmit the load safely, the depth of foundation has to be increased till a suitable soil stratum is met. In view of increased depth, such foundations are called deep foundations. Deep foundations are of the following types:

(i) Pile foundation.
(ii) Pier foundation.
(iii) Well foundation.

2. PILE FOUNDATION

Pile foundation is that type of deep foundation in which the loads are takento a low level by means of vertical members which may be of timber, concrete or steel. They may be subjected to vertical or lateral loads or a combination of vertical and lateral loads.

2.1 The situations in which a pile foundation is preferred

1. The load of the super structure is heavy and its distribution is uneven.
2. The top soil has poor bearing capacity.
3. The subsoil water is high so that pumping of water from the open trenches for the shallow foundations is difficult and uneconomical.
4. If deep strip foundation is attempted, timbering of sides is difficult to maintain or retain the soil of sides of the trench.
5. The structure is situated on the sea shore or river bed, where there is danger of scouring action of water.
6. Canal or deep drainage lines exist near the foundations.
7. The top soil is of expansive nature.

3. CLASSIFICATION OF PILES

3.1 Classification based on Function

Based on the function or the use, piles may be classified as:

(1) End bearing pile (2) friction pile (3) compaction pile (4) tension pile or uplift pile

(5) Anchor pile (6) fender pile and dolphins (7) batter pile (8) sheet pile.

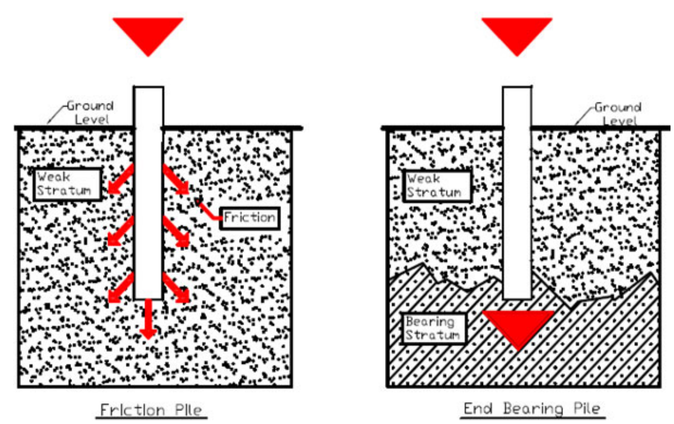

Fig. 3.1(a): Friction and end-bearing pile

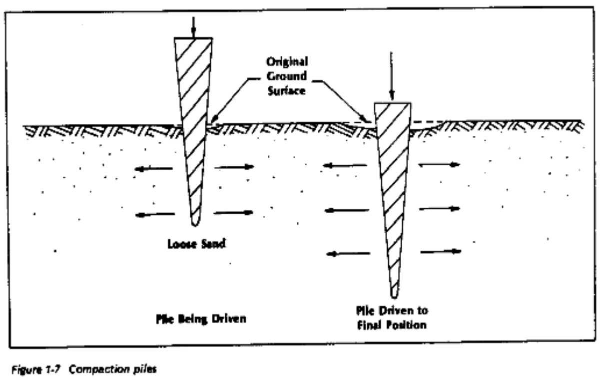

Fig. 3.1(b) Compaction piles

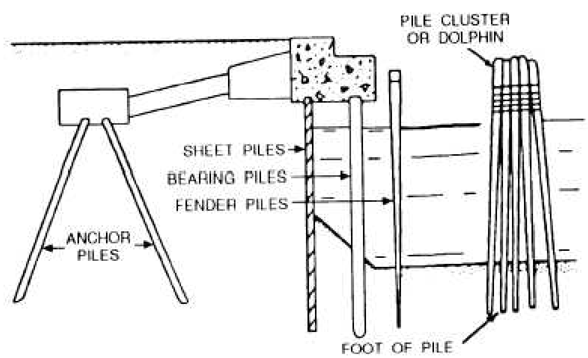

Fig. 3.1(c) Anchor piles

3.2 Classification based on Materials and Composition

1. **Timber piles**
2. **Concrete piles:**
   a. Pre-cast
   b. Cast-in-situ
      (i) Driven piles: Cased or Uncased
      (ii) Bored piles: Pressure piles, under-reamed piles and bored compaction piles.
3. **Steel piles**
   a. H-pile
   b. Pipe pile
   c. Sheet pile
4. **Composite piles**
   a. Concrete and timber
   b. Concrete and steel.

3.3 Classification based on Effect of Installation

1. Displacement piles
2. Non-displacement piles

4. LOAD TRANSFER MECHANISM OF PILES

Fig. 4. (a) gives a single pile of uniform diameter and length L driven into a homogeneous mass of soil of known physical properties.

When the ultimate load applied on the top of the pile is Q_u, a part of the load is transmitted to the soil along the length of the pile and the balance is transmitted to the pile base. The probable load distribution along the pipe with the increase in the top load is given in Fig. 4.(b). If the settlement of top of the pile is measured at every stage of loading after equilibrium condition is reached a load-settlement curve of the type shown in Fig. 4(c) can be obtained. When the load on the pile is very much lower than the ultimate load Q_u, the load is entirely taken by friction. For example, a load Q_1 on the pile Fig. 4(b), this load is transferred to soil within the length L_1. Only at high loads, such as loads greater than Q_2, a part of these loads is transferred to the base of the pile.

Fig. 4(d) gives the result of an actual load test in the field. It gives an idea of distribution of load between the shaft and base of the pile.

When the pile reaches the ultimate load Q_u, the load transmitted to the soil along the length of the pile is called the ultimate skin load Q_f and that transmitted to the base is called as the point load Q_b. the total ultimate load is a sum of these two expressed as

$$Q_u = Q_b + Q_f = q_b A_b + f_s A_s$$

Where q_b = ultimate unit bearing capacity of the pile at the base

A_b = bearing area of the base of the pile

As = total surface area of pile embedded below ground surface

f_s = ultimate unit skin friction

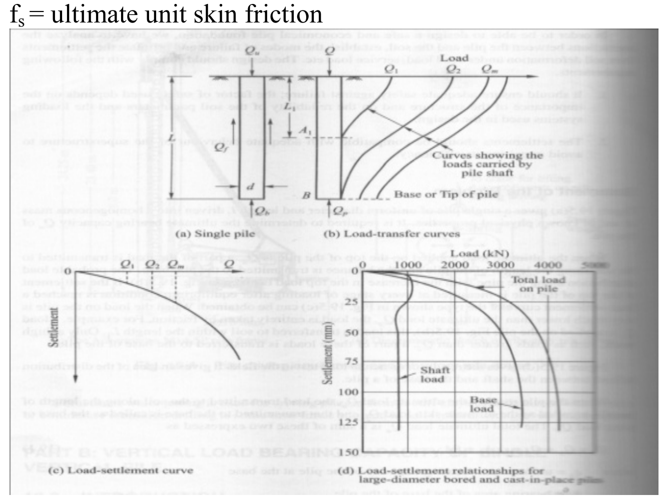

Fig. 4: Load transfer mechanics

5. PILE LOAD TEST

The pile load test is the direct method for determining the allowable load piles:

Types of test:

i) Vertical pile load test

ii) Cyclic pile load test (Vertical)

iii) Lateral pile load test

iv) Pull out test

Generally, vertical load test is carried out to establish load settlement relationship under compression and determine the allowable load on pile. The other two types of tests may be carried out only when piles are required to resist large lateral loads or uplift loads.

5.1: Vertical pile load test

Two categories of tests are usually carried out
i) Initial test
ii) Routine test

Initial test
This test is carried out on test pile to estimate the allowable load or to predict the settlement at a working load. A test pile is a pile which is used only in a load test and does not carry the load of the superstructure. The minimum load on test pile should be twice the safe load (Safe load calculated by static formula) or the value of which the total settlement attains $1/10^{th}$ of pile diameter for single pile or 40mm in case pile groups whichever occurs earlier.

Routine test
Routine test is performed on working pile as a check and to access the displacement corresponding to the working load. A working pile is a pile which is driven or cast in situ along with other piles to carry load from the superstructure. This type of pile is act as a part of foundation. The load on piles should be 1.5 times the safe load or upto the load at which total settlement attains a value of 12mm for single pile or 40mm for group of pile whichever occurs earlier.

6. METHODS OF CARRYING OUT VERTICAL PILE LOAD TEST

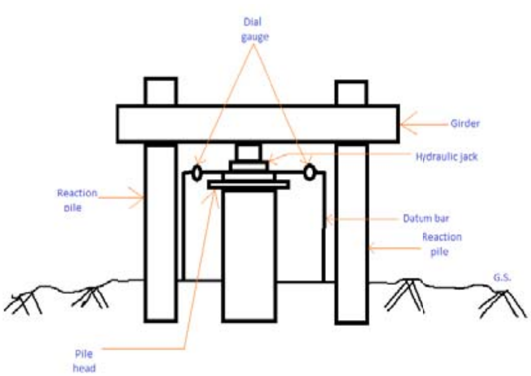

Fig. 6: Vertical pile load test

A vertical pile load test assembly is shown in figure. It consists of-

i) An arrangement to take the reaction of the load applied on the pile head.
ii) A hydraulic jack of sufficient capacity to apply load on the pile head, and
iii) A set of three dial gauges to measure settlement of the pile head

Load application:
Load test may be of two types:
(a) Continuous load test
(b) Cyclic load test

Continuous load test*:* (As per IS: 2911 part iv (1979))
Test procedure:
(i) The load is applied in a equal increment of $1/5^{th}$ of assume safe load or up to failure.
(ii) It's loading is maintained constant till the rate of settlement recorded by dial gauge is .02 mm/hour.
(iii) After completion of test the load-settlement graph is to be plotted.

Cyclic load test
Test procedure:
(i) The load is raised to a particular level, then reduced to zero, again raised to higher level and reduced to zero.
(ii) Settlements are recorded at each increment or decrement of load.
(iii) Cyclic load tests help to separate frictional load from point load.

Allowable load on a single pile may be obtained by the smaller of following
i) 50% of ultimate load at which the total settlement equals $1/10^{th}$of diameter in case of uniform pile and 75% of pile diameter in case of under-reamed pile.
ii) $2/3^{rd}$of ultimate load which causes a total settlement of 12 mm.

Allowable load on a group of pile shall be the smaller of following
i) Final load at which total settlement attains a value of 25 mm.
ii) $2/3^{rd}$of the final load at which a total settlement attains a value of 40 mm.

7. PILE GROUPS SUBJECTED TO VERTICAL LOADS

7.1 Spacing of Piles

Pile spacing. Piles in a group should be spaced so that the bearing capacity of the group is optimum. The optimum spacing for driven piles is 3 to 3.5B (Vesic 1977) or 0.02L + 2.5B, where L is the embedded length of the piles (Canadian Geotechnical Society 1985). Pile spacing should be at least 2.5 B. the spacing of piles also depends upon the method of installation.

7.2 Typical Arrangements of Piles in Groups

For friction piles, the minimum spacing recommended is 3*d* where *d* is the diameter of the pile. For end-bearing piles passing through relatively compressible strata, the spacing of piles shall not be less than 2.5*d*. For compaction piles, the spacing may be 2*d*. Typical arrangements of piles in groups are shown in the figure.

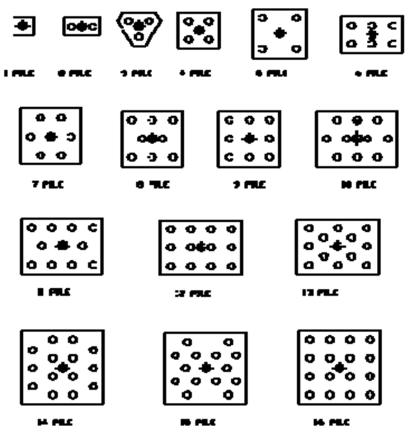

Fig. 7.2: Typical arrangements of piles in groups

8. SETTLEMENT OF A PILE GROUP

The vertical movement that occurs at the level of the pile cap is largely due to settlement of the soil supporting the pile. This has to be restricted to a value within the permissible settlement for the structure in question. The settlement of a group of piles is more than the settlement of a single pile even when the load on the single pile and the load on each pile of the pile group are the same. This is because of the fact that the zone of influence of a pile group is much deeper than that of a single pile. In addition, in the case of driven piles in sand, the larger thickness of soil contributing to settlement is also more compressible than the soil below a single pile which can be regarded as pre-compressed on account of the pile driving.

The total settlements of a pile groups may be calculated by making use of consolidation settlement equations. The problem involves evaluating the increase in stress Δp beneath a pile group when the group is subjected to a vertical load Q_g. The computation of stresses depends on the type of the soil through which the pile passes. The methods of computing the stresses are explained below:

1. The soil in the first group given in (a) of the fig.5 is homogeneous clay. The load Q_g is assumed to act on a fictitious footing at a depth 2/3L from the surface and distributed over the sectional area of the group. The load on the pile group acting at this level is assumed to spread out at a 2 : 1 slope, in order to work out the value of stress increases at the mid-depth of the clay stratum. The presence of the piles below this depth is ignored.
2. In the second group in (b) of the figure, the pile passes through a very weak layer of depth L_1 and the lower portion of length L_2 is embedded in a strong layer. In this case, the load Q_g is assumed to act at a depth equal to 2/3 L_2 below the surface of the strong layer and spreads at a 2:1 slope as before.
3. In the third case shown in (c) of the figure, the piles are point bearing piles. The load in this case is assumed to act at the level of the firm stratum and spreads out at a 2:1 slope.

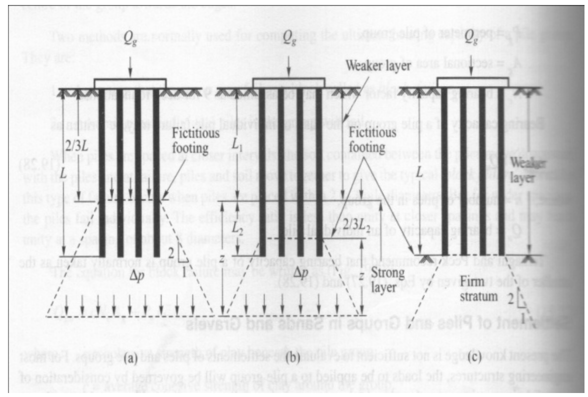

Fig. 8: Settlement of pile groups in clay soils

9. CONCLUSION

From this experiment we came to learn many things about pile foundation. Its uses, importance, etc. From this experiment we came to know that piles can be found in many different sizes and shapes. Most are constructed out of steel, although concrete and timber can also be used.

It is seen from the experiment that, it is used when there is no firm bearing strata exists at any reasonable depth and when the loading is uneven.

The art of driving piles were well established in Roman times and the details of such foundations were recorded by foundation. Modern pile driving started with the first steam pile drivers, invented by Nasmyth in 1845.

Hence the project will first clarify the classification of pile foundation so as to eliminate all the illusions and misunderstandings about pile foundation. We would like to thank our teachers for giving us such projects which inspired us to learn about pile foundation.

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